Rotorcraft Loss of Control In-Flight:

The need for research to support increased fidelity in flight training devices, including analogies with upset recovery for fixed-wing aircraft

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Overview

• Rotary wing accident trends
• Fixed wing LOC-I/UPRT activities
• Rotary wing safety initiatives
• Simulation fidelity research
• Opportunities in current modelling & simulation, training
• Concluding remarks and future activities
ROTORCRAFT ACCIDENT TRENDS
No Accidents – *That’s* the Objective
Franklin D Harris, 26th Alexander A. Nikolsky Lecture

IHST initiated a program with the goal to reduce the worldwide helicopter accident rate by 80% in 10 years (by 2016)
Accident Categorisation

- USJHS analysis team completed an analytical review of three years of U.S. helicopter accident data from 523 different accidents.

![Accidents by Top 5 Occurrence Categories](chart.png)

Example accident - NTSB Identification: CEN10FA509

- Dark night instrument meteorological conditions prevailed at the time of the accident.
- The last minute of data depicted a turn to the left, a turn to the right, a reversal to the left, a reversal back to the right, and then a final reversal to the left.
- “…probable cause(s) of this accident [may be] the pilot’s loss of aircraft control, due to spatial disorientation, resulting in the in-flight separation of the main rotor and tail boom”
Intervention Strategies

“Inadequate pilot judgment and the subsequent poor decision(s) or non-decision were found to be pervasive in most non-material failure types of accidents and must be addressed.”

- Inflight Power/Energy Management Training
- **Simulator Training - Advanced Manoeuvres**
- Enhanced Aircraft Performance & Limitations Training
- CFI Training and Refresher on Advanced Handling, Cues, and Procedures
- Emphasis for Maintaining Cues Critical to Safe Flight
DEVELOPMENT OF A FIXED WING UPSET PREVENTION AND RECOVERY TRAINING (UPRT) PROGRAMME
# Fixed Wing Accident Rates/Causes


<table>
<thead>
<tr>
<th>Category</th>
<th>Fatalities</th>
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<tbody>
<tr>
<td>LOC-I</td>
<td>1345</td>
</tr>
<tr>
<td>CFIT</td>
<td>1</td>
</tr>
<tr>
<td>RE (Landing) + APC + USOS</td>
<td>35</td>
</tr>
<tr>
<td>UNK</td>
<td>0</td>
</tr>
<tr>
<td>SCF-PP</td>
<td>12</td>
</tr>
<tr>
<td>FUEL</td>
<td>0</td>
</tr>
<tr>
<td>RE (Takeoff)</td>
<td>38</td>
</tr>
<tr>
<td>RAMP</td>
<td>6</td>
</tr>
<tr>
<td>MAC</td>
<td>7</td>
</tr>
<tr>
<td>F-NI</td>
<td>9</td>
</tr>
<tr>
<td>OTHR</td>
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</tr>
<tr>
<td>RAMP</td>
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<tr>
<td>MAC</td>
<td>0</td>
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<td>F-NI</td>
<td>0</td>
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<tr>
<td>OTHR</td>
<td>1</td>
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<tr>
<td>RAMP</td>
<td>1</td>
</tr>
<tr>
<td>USOS</td>
<td>0</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Number of fatal accidents (62 total)</th>
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<tr>
<td>LOC-I</td>
</tr>
<tr>
<td>CFIT</td>
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<td>RAMP</td>
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<td>USOS</td>
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</tbody>
</table>
CATEGORISATION OF F/W LOC-I

- LOC-I is a loss of aircraft control whole, or deviation from intended flightpath, in flight.
- LOC-I accidents result from failure to prevent or recover from a stall or upset
- Three causal categories:
  - Environmental (windshear, icing, wake vortex)
  - System failure (autopilot, flight control system)
  - Pilot Induced (disorientation, misuse of controls/automation)
Significant LOC-I Accidents & Causes

• In 2008, Lambregts concluded that Stall is the primary causal factor to LOC-I.

• Since 2008, the following LOC-I accidents were reported, all of which involved stall or low energy:
  – Colgan 3407
  – Turkish 1951
  – Air France 447
  – AirAsia 8501
  – Air Algérie 5017
  – Asiana 314
International Committee for Aviation Training in Extended Envelopes ICATEE (2009 - )

• 80+ members: manufacturers, airlines, national aviation authorities and safety boards, simulator manufacturers, training providers, research institutions and pilot representatives

• ICATEE thoroughly analysed the causes of LOC-I and addressed both the training and technology solutions.

• Technology includes:
  – Enhanced flight dynamics models of post-stall behaviour
  – Mathematical models to represent effects due to icing (not just weight increase)
  – Type-representative models (models do not need to be exact per aircraft type, but support the training objectives)
Industry Reaction

- Analysis of the causal factors:
  - Improper/inadequate training, including maintaining altitude during stall recovery
  - Lack of emphasis on reducing AoA in stalls; emphasis on wrong recovery techniques
  - **Limited attention to awareness and recognition**, and too much on “recovery”
  - Limitations in academic knowledge of instructors and pilots
  - Lack of regulations or consistent training standards
  - **Limitations in flight simulator fidelity beyond the normal flight envelope**
    - Inadequate models and validation of flight simulators regarding engine/airframe icing

- RAeS ICATEE drove changes, incorporated into ICAO 10011 “Manual of Aeroplane UPRT”

- Adopted provisions into regulations (FAA, EASA, others), requiring structured UPRT & Stall training
Current ICAO regulations

• ICAO 10011 requires:
  – Enhanced academics for all pilots and instructors (bridge training)
  – Repeat of UPRT exercises on recurring basis every 2-3 years
  – Ensure that simulator-based training is conducted within valid simulator envelope: avoid negative training
  – Develop competencies, since UPRT is not a “testing” requirement
Lessons Learned from Developing UPRT

• Required an **integrated approach** across the fixed wing community – **including training medium**
• Type Representative models are suitable for UPRT. This is about **enhancing current training practices**, not “perfecting” simulators
• **Academics!**
• **Enhancements require validation by SME pilots**, who must be properly qualified to assess the enhancements
• Don’t miss the forest for the trees: Enhance the training benefits!

• EASA 2017-13 Update of flight simulator training devices requirements
  – The European Plan for Aviation Safety highlights the importance of training tools modernisation
Can F/W UPRT be directly applied to R/W?

• Transferable
  – Focus on prioritization through causal factors
  – 3D Mental Model
  – Startle Management
  – Development of skills for better awareness and recognition
  – Apply proper CRM where applicable
  – LOC-I contributing factors similar
  – Academics!

• Non-Transferable
  – Helicopters are different and varied!
  – Push-Roll-Power-Stabilise F/W approach could be dangerous
  – Differing levels of augmentation
81 Improve Simulator Modelling for Outside-the-Envelope Flight Conditions
127A Training for Recognition/Recovery of Spatial Disorientation (SD)

- 52 fatal accidents (2009-2013) where LOC-I occurred during basic manoeuvres (e.g. hover) and during unsuccessful attempted recovery from potentially unsafe conditions (e.g. LTRE)
- FAA, industry & academia to review and provide recommendations for improving simulator mathematical/physics models
- Create helicopter unique SD training products to include simulation technology.
- Define SD scenarios for emphasis in training products
- http://www.ushst.org/

*U.S. Helicopter Safety Team (USHST), Report Helicopter Safety Enhancements: Loss of Control – Inflight, Unintended Flight in IMC, and Low-Altitude Operations October 2017*
European Activities & Training Materials

EHEST

• “Training and Testing of Emergency and Abnormal Procedures in Helicopters”
• “Safety Considerations: Methods To Improve Helicopter Pilots’ Capabilities”
• HeliOffshore
  – Operational Effectiveness e.g. HTAWS, APM
  – Reliability and Resilience, e.g. HUMS
  – Safety Intelligence
  – info@helioffshore.org
ROTORCRAFT FLIGHT SIMULATION RESEARCH OPPORTUNITIES
Simulation Fidelity: GARTEUR AG-12

Validation Criteria for Helicopter Real-Time Simulation Models

- Appropriateness of some CS-FSTD H criteria should be questioned
- Required tolerances for high fidelity sensitive to nature of manoeuvre flown
- A model that satisfies CS tolerances may give different HQs compared to flight test
- Need to bridge the gap between pilot subjective opinion and formal metrics
- Determine an objective means for assessing overall fidelity of a simulator
- Off axis response

Simulation Fidelity: Lifting Standards

• Flight Test Database for Predictive and Perceptual Fidelity Assessment

• Predictive fidelity research:
  – Use a System Identification approach, to explore the fidelity of existing rotorcraft simulation models and to produce a rational, **physics based approach** to simulation fidelity improvement

• Perceptual Fidelity
  – Development of metrics
  – **Simulation Fidelity Rating Scale**


Opportunities in Current Modelling & Simulation, Training

• Completely physics based, “high fidelity” real-time simulation models
  – Blade modelling
  – Interactional aerodynamics
  – Inflow and wake modelling
  – Datasets for model validation

• Simulator Training
  – Effective scenarios
  – Cueing
  – Subjective assessments

Concluding Remarks & Future Work

- Excellent work has been undertaken internationally to reduce rotorcraft accident rates
- LOC-I is still one of the main contributing factors in rotorcraft accidents
- The fixed wing community developed UPRT programme to mitigate LOC-I accidents
- Some elements of UPRT can be transferred to rotorcraft

Future work...

- Development of an international co-ordinated programme, similar to ICATEE, to identify key simulation areas to enhance rotorcraft safety
- Dedicated technical conference
- Improvements in rotorcraft physics based modelling & standards
- Increased use of flight simulation for LOC-I training across all platforms
- Use of new technologies e.g. VR to support safety improvements
Questions?

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FY 18 – Total Accidents by Industry (Oct 2017 - July 2018)

FAA Rotorcraft Standards Branch AIR-680 Monthly Accident Briefing July 2018
LOC-I Occurrence Category
USHST Helicopter Safety Enhancements

• Safety Culture
• Detection and Management of Risk During Flight
• Pre-flight Inspection
• Autorotation Training – new research?
• SAS Autopilots in Light Helicopters
• Flight Data Monitoring
• Enhanced Vision Systems
• Improved transition training
• Competency based training
• http://www.ushst.org/